CLAIMS

1. A multi-stage optical amplifier, comprising:

an amplifier including at least a distributed Raman amplifier fiber and a discrete amplifier fiber, the amplifier configured to be coupled to at least one signal source that produces a plurality of signal wavelengths $\lambda_{s;}$ and at least a first pump source that produces one or more pump beam wavelengths $\lambda_{p;}$

a signal input port coupled to the amplifier;

a signal output port coupled to the amplifier, the distributed Raman and discrete amplifier fibers being positioned between the signal input port and the signal output port;

a first pump input port coupled to a first end of the distributed Raman amplifier fiber;

a second pump input port coupled to a second end of the distributed Raman amplifier fiber, the first end being located closer to the signal input port than the second end; and

a third pump input port coupled to the discrete amplifier fiber.

2. The multi-stage optical amplifier of claim 1, wherein the first and second pump input ports are configured to couple pump light into the distributed Raman amplifier fiber.

3. The multi-stage optical amplifier of claim 1, wherein the second and third pump input ports are located at a first location and the first pump input port is located at a second location that is distanced from the first location.

4. The multi-stage optical amplifier of claim 3, wherein the second location is distanced in an amount of at least 20 km relative to the first location.

5. The multi-stage optical amplifier of claim 1, wherein the discrete amplifier fiber is a discrete Raman amplifier fiber.

6. The multi-stage optical amplifier of claim 1, wherein the first pump input port is coupled to a first pump source, and the second pump input port is coupled to a second pump source.

7. The multi-stage optical amplifier of claim 5, wherein the distributed and discrete Raman amplifier fibers have lengths greater than or equal to 200 m.

8. The multi-stage optical amplifier of claim 1, wherein the one or more pump beam wavelengths λ_p are in the range of 1300 nm to 1530 nm.

9. The multi-stage optical amplifier of claim 1, wherein an effective optical noise figure of the distributed Raman amplifier fiber is less than an optical noise figure of the discrete amplifier fiber for at least a portion of the plurality of signal wavelengths λ_S.

10. The multi-stage optical amplifier of claim 1, wherein the discrete amplifier fiber has a higher gain than the distributed Raman amplifier fiber for at least a portion of the plurality of signal wavelengths λ_S.

11. The multi-stage optical amplifier of claim 5, wherein at least one of the distributed and discrete Raman amplifier fibers is a dispersion compensating fiber.

12. The multi-stage optical amplifier of claim 1, wherein the distributed Raman amplifier fiber has an effective optical noise figure of less than 8 dB for at least a portion of the plurality of signal wavelengths λ_S.

13. The multi-stage optical amplifier of claim 1, wherein the discrete amplifier fiber has a gain level of at least 5 dB for at least a portion of the plurality of signal wavelengths λ_S.

14. The multi-stage optical amplifier of claim 5, wherein the amplifier includes a second discrete Raman amplifier fiber.

15. The multi-stage optical amplifier of claim 14, further comprising:

a pump shunt coupled to the optical fiber, wherein at least a portion of the one or more pump wavelengths λ_p is coupled between the discrete Raman amplifier fiber and the second discrete Raman amplifier fiber.

16. The multi-stage optical amplifier of claim 6, wherein each of the first and second pump sources is a laser diode pump source.

17. The multi-stage optical amplifier of claim 1, further comprising:

at least a first lossy member positioned between the signal input port and signal output port, the at least first lossy member being lossy in at least one direction.

18. The multi-stage optical amplifier of claim 17, wherein the at least first lossy member includes an optical isolator.

19. The multi-stage optical amplifier of claim 17, wherein the at least first lossy member includes an add/drop multiplexer.

20. The multi-stage optical amplifier of claim 17, wherein the at least first lossy member includes a gain equalization member.

21. The multi-stage optical amplifier of claim 17, wherein the at least first lossy member includes a dispersion compensation member.

22. The multi-stage optical amplifier of claim 17, wherein the at least first lossy member includes a WDM coupler.

23. The multi-stage optical amplifier of claim 5, wherein the amplifier includes a transmission fiber.

24. The multi-stage optical amplifier of claim 23, wherein the amplifier includes a dispersion compensating fiber.

25. The multi-stage optical amplifier system of claim 24, wherein the dispersion compensating fiber has an opposite sign of dispersion slope and an opposite sign of dispersion relative to the transmission fiber.

26. The multi-stage optical amplifier of claim 23, wherein the transmission fiber includes the distributed and discrete Raman amplifier fibers.

27. The multi-stage optical amplifier of claim 26, wherein the amplifier includes a dispersion compensating fiber.

28. The multi-stage optical amplifier of claim 27, wherein the dispersion compensating fiber has an opposite sign of dispersion slope and an opposite sign of dispersion relative to the cumulative dispersion of the entire transmission fiber excluding any dispersion compensating fiber portion of the transmission fiber.

29. A multi-stage optical amplifier, comprising:

an optical fiber including at least a distributed Raman amplifier fiber

and a discrete amplifier fiber, the optical fiber configured to be coupled to at least one signal source that produces a plurality of signal wavelengths λ_s and at least two pump sources that produce one or more pump beam wavelengths λ_p, wherein at least a portion of one of the distributed Raman amplifier fiber and the discrete amplifier fiber is a dispersion compensating fiber;

a signal input port coupled to the optical fiber;

a first pump input port positioned between the signal input port and the distributed Raman amplifier fiber;

a second pump input port, the distributed Raman amplifier fiber being positioned between the signal input port and the second pump input port and the discrete amplifier fiber being positioned between the second pump input port and signal output port; and

a third pump input port configured to pump the discrete Raman amplifier fiber.

30. The multi-stage optical amplifier of claim 29, wherein the dispersion compensating fiber has a zero dispersion point that is shifted to wavelengths greater than 1500 nm using the waveguide dispersion property.

31. The multi-stage optical amplifier of claim 29, wherein the discrete amplifier fiber is a discrete Raman amplifier fiber.

32. The multi-stage optical amplifier of claim 31, wherein the distributed and discrete Raman amplifier fibers have lengths greater than or equal to 200m.

33. The multi-stage optical amplifier of claim 29, wherein the one or more pump beam wavelengths λ_p are in the range of 1300 nm to 1530 nm.

34. The multi-stage optical amplifier of claim 29, wherein the distributed Raman amplifier fiber has an effective optical noise figure of less than 8 dB for at least a portion of the plurality of signal wavelengths λ_S.

35. The multi-stage optical amplifier of claim 29, wherein the discrete amplifier fiber has a gain level of at least 5 dB for at least a portion of the plurality of signal wavelengths λ_S.

36. The multi-stage optical amplifier of claim 29, further comprising:
at least a first lossy member positioned between the signal input port and the signal output port, the at least first lossy member being lossy in at least one direction.

37. The multi-stage optical amplifier system of claim 29, wherein the dispersion compensating fiber has an opposite sign of dispersion slope and an opposite sign of dispersion relative to the cumulative dispersion of the entire optical fiber excluding the dispersion compensating fiber portion of the optical fiber.

38. A multi-stage optical amplifier, comprising:

an optical fiber including at least a distributed Raman amplifier fiber and a discrete amplifier fiber, the amplifier configured to be coupled to at least one signal source that produces a plurality of signal wavelengths λ_s; and at least a first pump source that produces one or more pump beam wavelengths λ_p;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber, the distributed Raman and discrete amplifier fibers being positioned between the signal input port and the signal output port;

a first pump input port coupled to the distributed Raman amplifier fiber;

a second pump input port coupled to the discrete amplifier fiber; and

a dispersion compensating member coupled to the optical fiber, wherein the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to at least a portion of the optical fiber.

39 The multi-stage optical amplifier of claim 38, wherein the dispersion compensating member is positioned between the distributed Raman amplifier fiber and the discrete amplifier fiber.

40. The multi-stage optical amplifier system of claim 38, wherein a portion of the optical fiber is the dispersion compensating member.

41. The multi-stage optical amplifier of claim 38, wherein at least a portion of the optical fiber includes a dispersion compensating fiber.

42. The multi-stage optical amplifier of claim 38, wherein the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to a majority of the optical fiber.

43. The multi-stage optical amplifier of claim 38, wherein the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to a cumulative dispersion of the entire optical fiber.

44. The multi-stage optical amplifier of claim 38, wherein the discrete amplifier fiber is a discrete Raman amplifier fiber.

45. The multi-stage optical amplifier of claim 44, wherein the

distributed and discrete Raman amplifier fibers have lengths greater than or equal to 200 m.

46. The multi-stage optical amplifier of claim 38, wherein the one or more pump beam wavelengths λ_p are in the range of 1300 nm to 1530 nm.

47. The multi-stage optical amplifier of claim 44, wherein at least one of the distributed and discrete Raman amplifier fibers is a dispersion compensating fiber.

48. The multi-stage optical amplifier of claim 44, wherein the optical fiber includes a second discrete Raman amplifier fiber.

49. The multi-stage optical amplifier of claim 48, further comprising:

a third pump input port coupled to the second discrete Raman amplifier fiber.

50. The multi-stage optical amplifier of claim 38, wherein the first pump source is a laser diode pump source.

51. The multi-stage optical amplifier of claim 38, further comprising:

at least a first lossy member positioned between the signal input port and the signal output port, the at least first lossy member being lossy in at least one direction.

52. A multi-stage optical amplifier, comprising:

an optical fiber including a first Raman amplifier fiber and a second Raman amplifier fiber, the optical fiber configured to be coupled to a signal source that produces a plurality of signal wavelengths λ_s and a pump source

that produces one or more pump wavelengths λ_p, wherein the one or more pump wavelengths λ_p are less than at least a portion of the plurality of signal wavelengths λ_s;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a dispersion compensating member coupled to the optical fiber; and

a pump shunt coupled to the optical fiber, wherein at least a portion of the one or more pump wavelengths λ_p is coupled between the first Raman amplifier fiber and the second Raman amplifier fiber.

53. The multi-stage optical amplifier of claim 52, wherein the optical fiber includes a transmission fiber and the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to at least a portion of the optical fiber.

54. The multi-stage optical amplifier of claim 52, wherein the optical fiber includes a transmission fiber and the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to a majority of the optical fiber.

55. The multi-stage optical amplifier of claim 52, wherein the optical fiber includes a transmission fiber and the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to a cumulative dispersion of the entire optical fiber.

56. The multi-stage optical amplifier of claim 52, wherein the pump shunt is coupled to the signal input port and the signal output port.

57. The multi-stage optical amplifier of claim 52, further comprising:

a distributed Raman amplifier coupled to the signal input port.

58. The multi-stage optical amplifier of claim 57, wherein at least a portion of the pump shunt is positioned between the distributed Raman amplifier and the signal input port.

59. The multi-stage optical amplifier of claim 52, wherein the one or more pump wavelengths λ_p are in the range of 1300 to 1530 nm.

60. The multi-stage optical amplifier of claim 52, further comprising:

a lossy member coupled to the optical fiber.

61. The multi-stage optical amplifier of claim 52, further comprising:

a lossy member coupled to the pump shunt.

62. The multi-stage optical amplifier of claim 52, wherein the pump shunt includes an optical fiber.

63. The multi-stage optical amplifier of claim 52, wherein at least a portion of at least one of the first and second Raman amplifier fibers is a dispersion compensating fiber.

64 The multi-stage optical amplifier of claim 63, wherein the optical fiber includes a transmission fiber and the dispersion compensating fiber has an opposite sign of dispersion slope and an opposite sign of dispersion relative to at least a portion of the optical fiber.

65. The multi-stage optical amplifier of claim 54, further comprising:

at least one WDM coupler to couple a pump path from the signal input port to the signal output port.

66. The multi-stage optical amplifier of claim 52, further comprising:

at least one laser diode pump source coupled to the pump input port.

67. A multi-stage optical amplifier system, comprising:

a plurality of transmitters that produce a plurality of signal wavelengths $\lambda_{s;}$

a multi-stage optical amplifier including,

at least a distributed Raman amplifier fiber and a discrete amplifier fiber, the multi-stage optical amplifier being coupled to the plurality of transmitters; and configured to be coupled to at least a first pump source that produces one or more pump beam wavelengths $\lambda_{p,}$

a signal input port coupled to the amplifier,

a signal output port coupled to the amplifier, the distributed Raman and discrete amplifier fibers being positioned between the signal input port and the signal output port,

a first pump input port coupled to a first end of the distributed Raman amplifier fiber,

a second pump input port coupled to a second end of the distributed Raman amplifier fiber, the first end being located closer to the signal input port than the second end,

a third pump input port coupled to the discrete amplifier fiber; and

a plurality of receivers coupled to the multi-stage optical amplifier.

68 The multi-stage optical amplifier system of claim 67, wherein the first and second pump input ports are configured to couple pump light into the distributed Raman amplifier fiber.

69 The multi-stage optical amplifier system of claim 67,

wherein the discrete amplifier fiber is a discrete Raman amplifier fiber.

70. The multi-stage optical amplifier system of claim 69, wherein the distributed and discrete Raman amplifier fibers have lengths greater than or equal to 200 m.

71. The multi-stage optical amplifier system of claim 69, wherein at least one of the distributed and discrete Raman amplifier fibers is a dispersion compensating fiber.

72. A multi-stage optical amplifier system, comprising:

a plurality of transmitters that produce a plurality of signal wavelengths $\lambda_{s;}$

a multi-stage optical amplifier including,

an optical fiber including at least a distributed Raman amplifier fiber and a discrete amplifier fiber, the multi-stage optical amplifier being coupled to the plurality of transmitters and configured to be coupled to at least two pump sources that produce one or more pump beam wavelengths λ_p, wherein at least a portion of one of the distributed Raman amplifier fiber and the discrete amplifier fiber is a dispersion compensating fiber;

a signal input port coupled to the optical fiber,

a first pump input port positioned between the signal input port and the distributed Raman amplifier fiber,

a second pump input port, the distributed Raman amplifier fiber being positioned between the signal input port and the second pump input port and the discrete amplifier fiber being positioned between the second pump input port and signal output port,

a third pump input port configured to pump the discrete

Raman amplifier fiber; and

a plurality of receivers coupled to the multi-stage optical amplifier.

73. The multi-stage optical amplifier system of claim 72, wherein the dispersion compensating fiber has a zero dispersion point that is shifted to wavelengths greater than 1500 nm using the waveguide dispersion property.

74 The multi-stage optical amplifier system of claim 72, wherein the discrete amplifier fiber is a discrete Raman amplifier fiber.

75. The multi-stage optical amplifier system of claim 74, wherein the distributed and discrete Raman amplifier fibers have lengths greater than or equal to 200m.

76. The multi-stage optical amplifier system of claim 72, wherein the dispersion compensating fiber has an opposite sign of dispersion slope and an opposite sign of dispersion relative to the cumulative dispersion of the entire optical fiber excluding the dispersion compensating fiber portion of the optical fiber.

77. A multi-stage optical amplifier system, comprising:

a plurality of transmitters that produce a plurality of signal wavelengths $\lambda_{s;}$

a multi-stage optical amplifier including,

an optical fiber including at least a distributed Raman amplifier fiber and a discrete amplifier fiber, the multi-stage optical amplifier being coupled to the plurality of transmitters and configured to be coupled to at least a first pump source that produces one or more pump beam wavelengths $\lambda_{p,}$

a signal input port coupled to the optical fiber,

a signal output port coupled to the optical fiber, the distributed Raman and discrete amplifier fibers being positioned between the signal input port and the signal output port,

a first pump input port coupled to the distributed Raman amplifier fiber,

a second pump input port coupled to the discrete amplifier fiber,

a dispersion compensating member coupled to the optical fiber, wherein the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to at least a portion of the optical fiber; and

a plurality of receivers coupled to the multi-stage optical amplifier.

78. The multi-stage optical amplifier system of claim 77, wherein the dispersion compensating member is positioned between the distributed Raman amplifier fiber and the discrete amplifier fiber.

79. The multi-stage optical amplifier system of claim 77, wherein the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to a majority of the optical fiber.

80. The multi-stage optical amplifier system of claim 77, wherein the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to a cumulative dispersion of the entire optical fiber.

81. The multi-stage optical amplifier system of claim 77,

wherein the discrete amplifier fiber is a discrete Raman amplifier fiber.

82. A multi-stage optical amplifier system, comprising:

a plurality of transmitters that produce a plurality of signal wavelengths λ_s;

a multi-stage optical amplifier including,

an optical fiber including a first Raman amplifier fiber and a second Raman amplifier fiber, the multi-stage optical amplifier being coupled to the plurality of transmitters and configured to be coupled to a pump source that produces one or more pump wavelengths λ_p, wherein the one or more pump wavelengths λ_p are less than at least a portion of the plurality of signal wavelengths λ_s,

a signal input port coupled to the optical fiber,

a signal output port coupled to the optical fiber,

a pump input port coupled to the optical fiber,

a dispersion compensating member coupled to the optical fiber,

a pump shunt coupled to the optical fiber, wherein at least a portion of the one or more pump wavelengths λ_p is coupled between the first Raman amplifier fiber and the second Raman amplifier fiber; and

a plurality of receivers coupled to the multi-stage optical amplifier.

83. The multi-stage optical amplifier system of claim 82, wherein the optical fiber includes a transmission fiber and the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to at least a portion of the optical fiber.

84. The multi-stage optical amplifier system of claim 82,

wherein the optical fiber includes a transmission fiber and the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to a majority of the optical fiber.

85. The multi-stage optical amplifier system of claim 82, wherein the optical fiber includes a transmission fiber and the dispersion compensating member has an opposite sign of dispersion slope and an opposite sign of dispersion relative to a cumulative dispersion of the entire optical fiber.

86. The multi-stage optical amplifier system of claim 82, further comprising:

a distributed Raman amplifier coupled to the signal input port.